§6. One-dimensional Kinetic Simulation on Collisional Bounded Plasma

Shao-ping Zhu, Ritoku Horiuchi and Tetsuya Sato

Study on collisional bounded plasma, especially on the sheath formation at a plasma boundary, is important because every laboratory plasma must be bounded by some confining structure. Kinetic treatment is necessary for an accurate description of this problem because the ion distribution has a large non-Maxwellian component. The first kinetic simulation on sheath formation of collisional plasma was proposed by T.Takizuka et al[1] as a model of divertor plasma. A more careful kinetic simulation on collisional bounded plasma was reported by Procassini et al[2].

In the present report, we give a self-consistent kinetic simulation study on one dimensional collisional bounded plasma. The basic equations are as follow;

$$\frac{\partial^2\phi}{\partial x^2} = -4\pi\rho, \qquad \frac{dv_{x,j}}{dt} = -\frac{q_j}{m_j}\frac{\partial\phi}{\partial x} + \frac{dv_{x,j}}{dt}|_{col}, \quad (1)$$

$$\frac{dv_{y,j}}{dt} = \frac{dv_{y,j}}{dt}|_{col}, \qquad \frac{dv_{z,j}}{dt} = \frac{dv_{z,j}}{dt}|_{col}, \quad (2)$$

$$\frac{dx_j}{dt} = v_{x,j}, \qquad \rho = \sum_j^N q_j S(x - x_j(t)) \quad (3)$$

Where N is the total number of particles, and S(x) is the form function of particles. $\frac{d\mathbf{V}_j}{dt}|_{col}$, $\frac{d\mathbf{V}_j}{dt}|_{col}$ and $\frac{d\mathbf{V}_j}{dt}|_{col}$ are the change of velocity due to Coulomb binary collision, which is done by Monte Carlo method based on ref.[3]. In the present simulation, the collisionality of system is enlarged numerically by reducing particle numbers in Debye cubic when we include collision by using Monte Carlo method(enlarge factor is 2000 in the following discussion), The simulation region is bounded by a symmetric boundary on the left side and a plate located on the right side.

The spatial profiles of potential at time $t = 4800$ are plotted in Fig.1 for three runs, where particle density was fixed at $5 \times 10^{13}\frac{1}{cm^3}$, but temperature was changed from 50 eV to 200 eV. It is clear that total potential drop increases as the collisionality grows up. The spatial profiles of temperature at time $t = 4800$ are plotted in Fig.2. The ion parallel temperature decreases as the collisionality increases and the ion perpendicular temperature decreases with increasing collisionality. These results are contrary to those of Ref.(2), but are physical. As we know, the ion perpendicular temperature is equal to source ion temperature(source ion temperature is 3 in the present cases) if ion is collisionless. Ion parallel temperature should be less than source ion temperature because the high speed ion escaped from system fast. As the collisionality increases, the energy exchange between the parallel and perpendicular component is enhanced. That is,

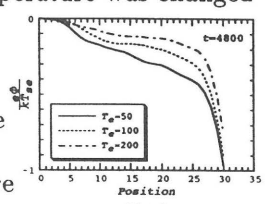

Fig.1

ion parallel temperature increases and ion perpendicular temperature decreases. Fig.2.c and Fig.2.d show that electron parallel temperature increases with increasing collisionality, but there is no increasing or decreasing tendency for electron perpendicular temperature as the the collisionality increases. The reason is that the parallel and perpendicular temperature are in equilibrium state for the strong collisionanlity case, but far from equilibrium for weak collisionanlity case. Fig.2.c shows that there is gradient in parallel temperature for strong collisionanlity case, but the parallel temperature is nearly spatial uniform for weak collisionality case except the sheath region. The reason is that the parallel motion of electron is decelerated by source and presheath potential drops, and the source and presheath potential drops of strong collisionanlity case are much greater than those of weak collisionanlity case.

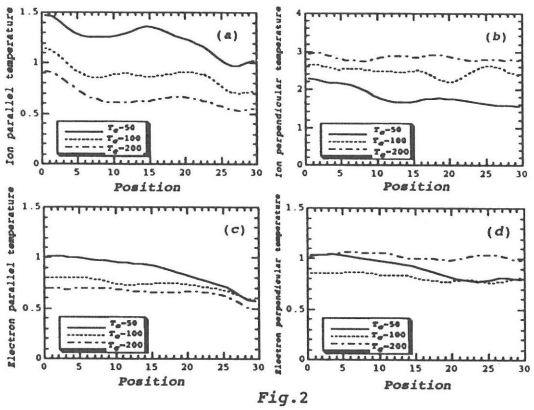

Fig.2

We plot in Fig.3 the x-component of distribution function $f_\alpha(v_x)$ averaged over presheath region at time $t = 4800$ for two cases of temperature 50 eV(Fig.3.a, Fig.3.b) and 200 eV(Fig.3.c, Fig.3.d), where open circles are the simulation results and the solid lines are given by shifted Maxwellian distribution functions. X-component of electron is described by Maxwellian distribution function well for both weak and strong collisionality. For the case of strong collisionality, x-component of ion satisfies shifted Maxwellian distribution function.

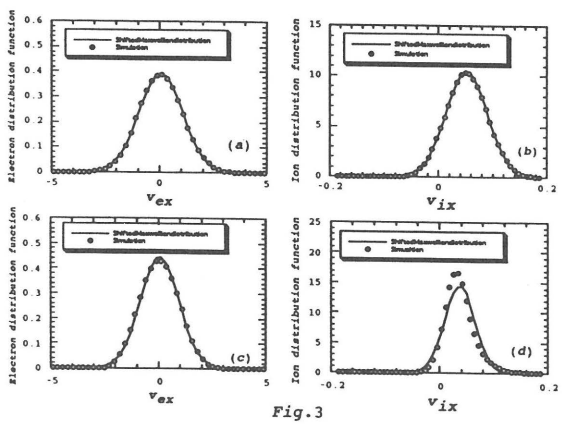

Fig.3

1)T.Takizuka, et al, J.Nucl.Mater. 128-129, 104(1984).
2)R.J.Procassini et al, Phys.Fluids B 3, 1876(1991).
3)W. X. Wang et al, Nucl. Fusion 36, 1633(1996).